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(54) **PROTECTIVE SKIN FOR AIRCRAFT**

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(57) **ABSTRACT**

A protective skin (143a, 143b) for an aircraft is disclosed. The protective skin (143a, 143b) forms the leading edges of wing members, horizontal stabilizers, and vertical fins. A portion of the skin material (143a, 143b) is removed in a selected pattern (155a, 157a, 159a, 161a, 155b, 157b, 159b, 161b) from the interior surface of the skin (143a, 143b). In the preferred embodiment, the interior surface of the skin is chemically etched and/or mechanically milled in oval and rectangular patterns so as to create crumple zones (155a, 157a, 159a, 161a, 155b, 157b, 159b, 161b) and generate progressive failure of the metal. This allows the leading edge to absorb the impact energy from a collision with a bird or other object, and prevent the bird or other object from penetrating through the leading edge into the substructure.

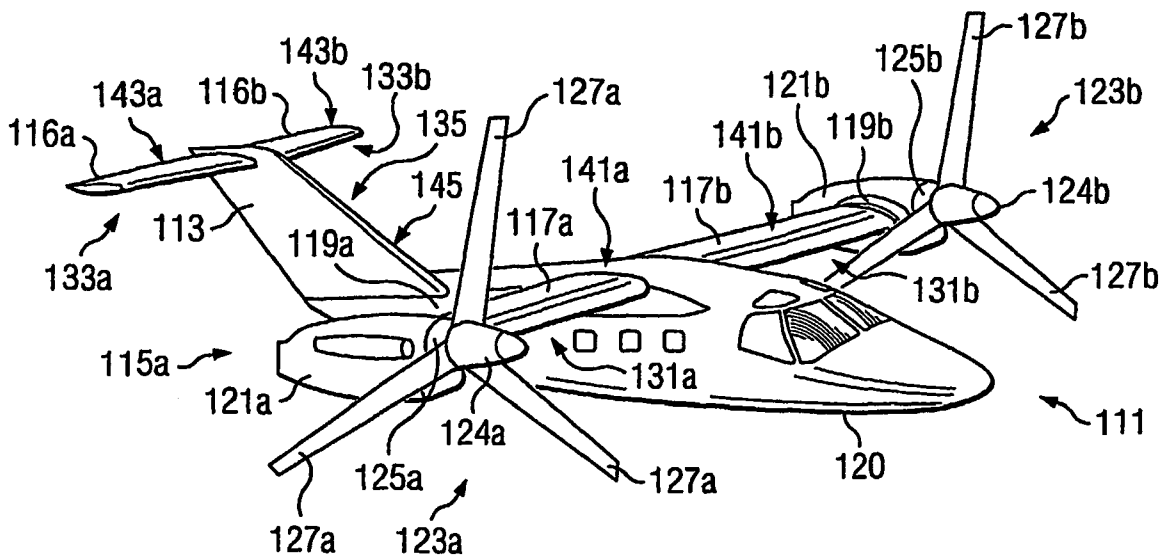
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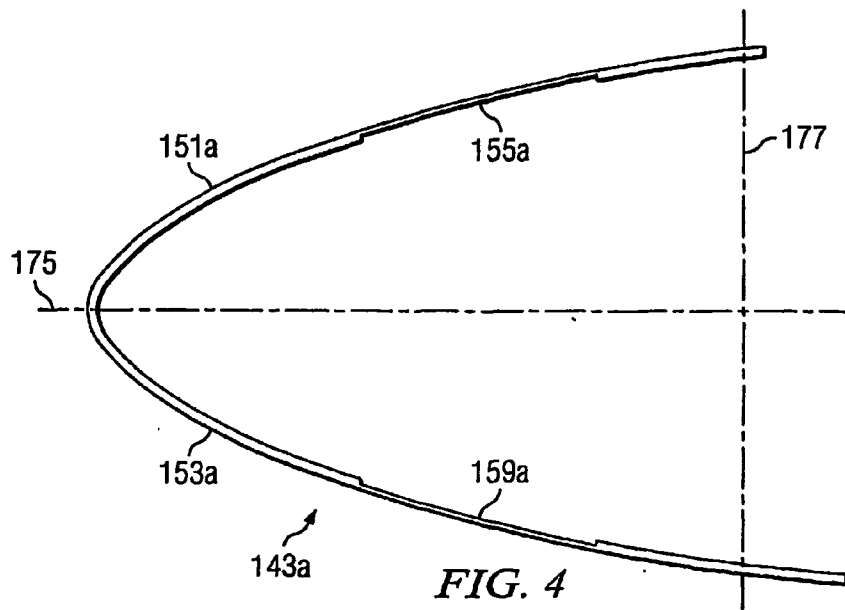
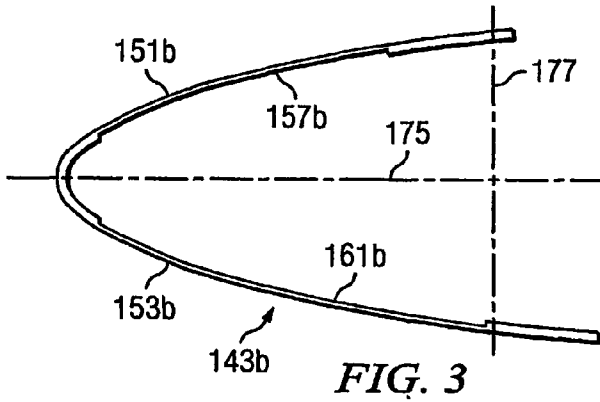
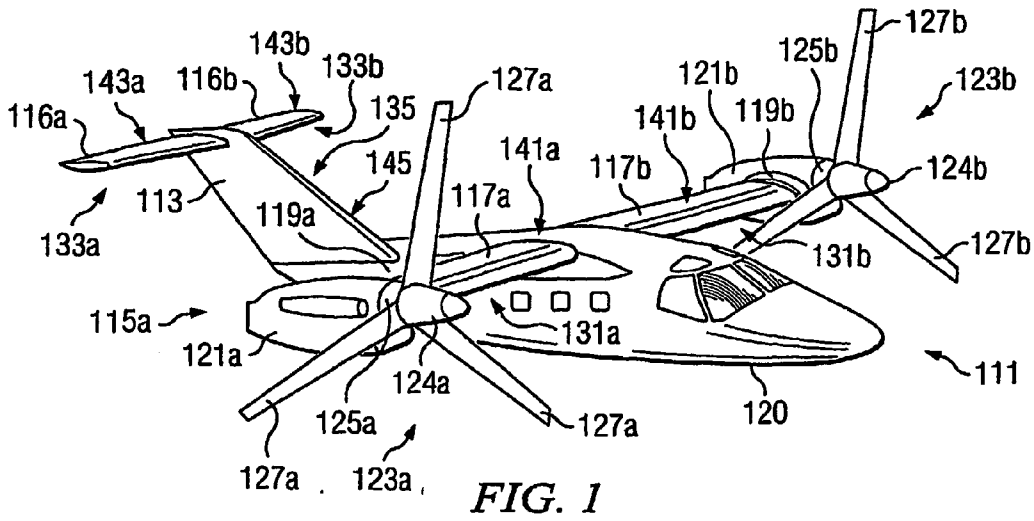
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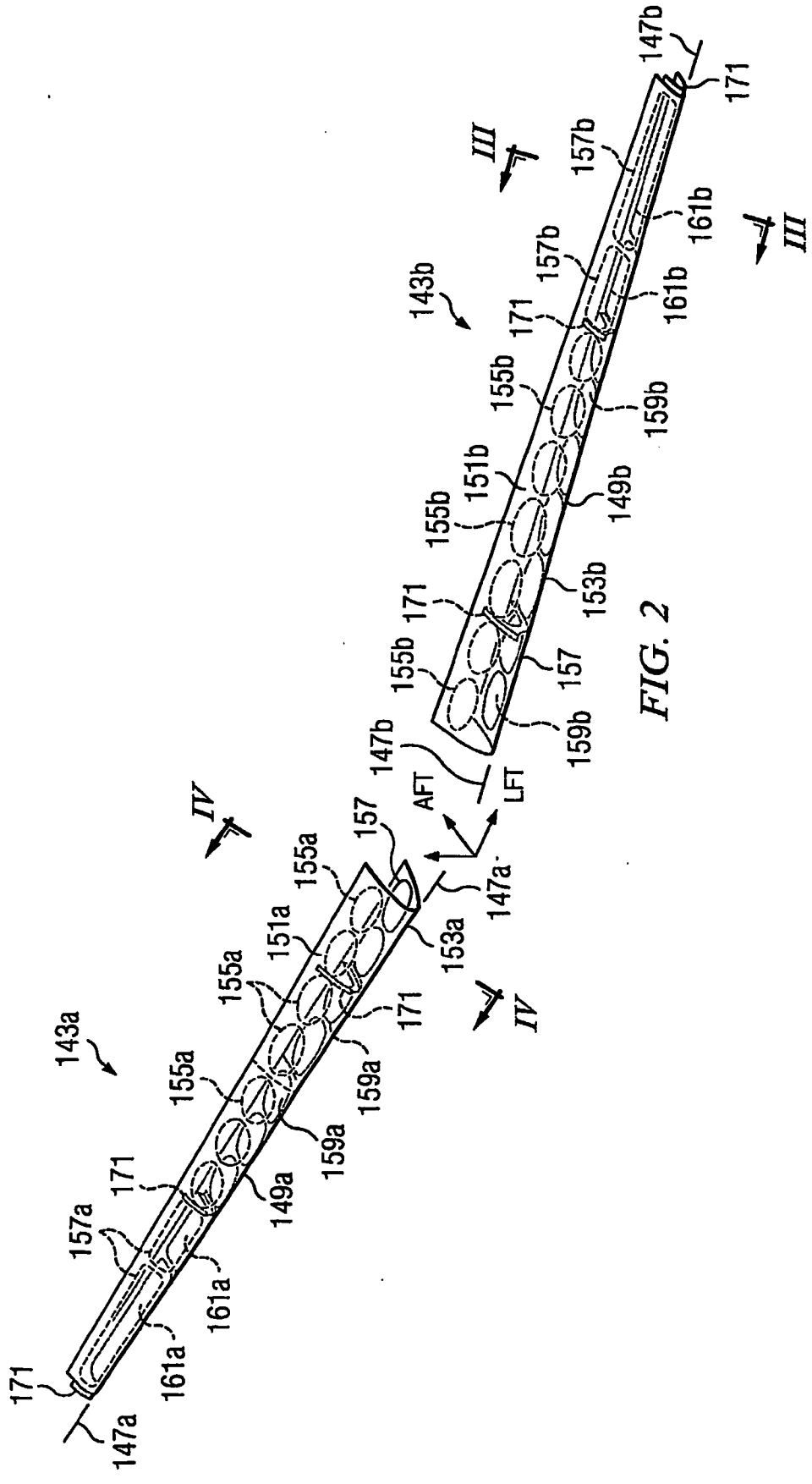


FIG. 2

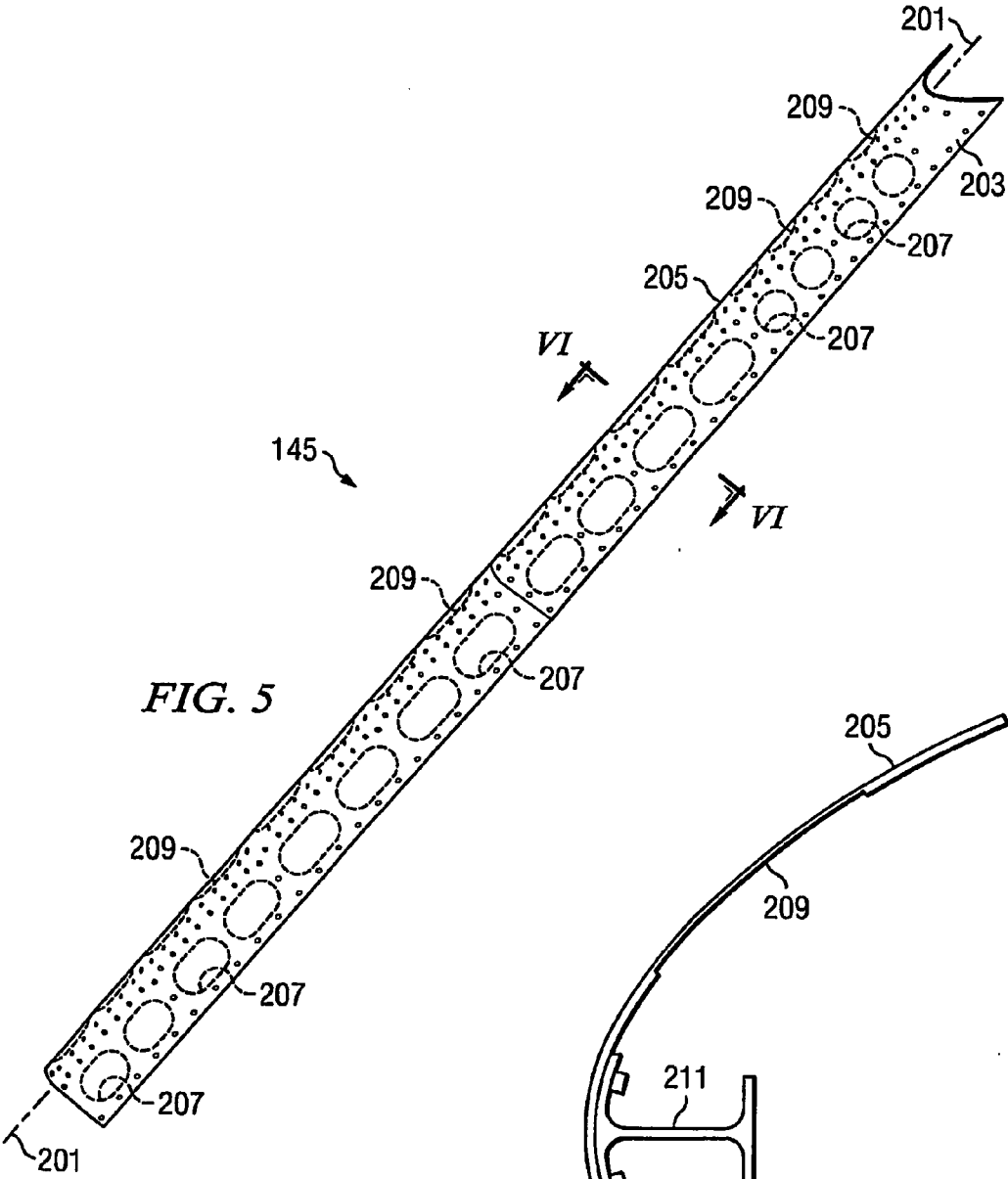


FIG. 5

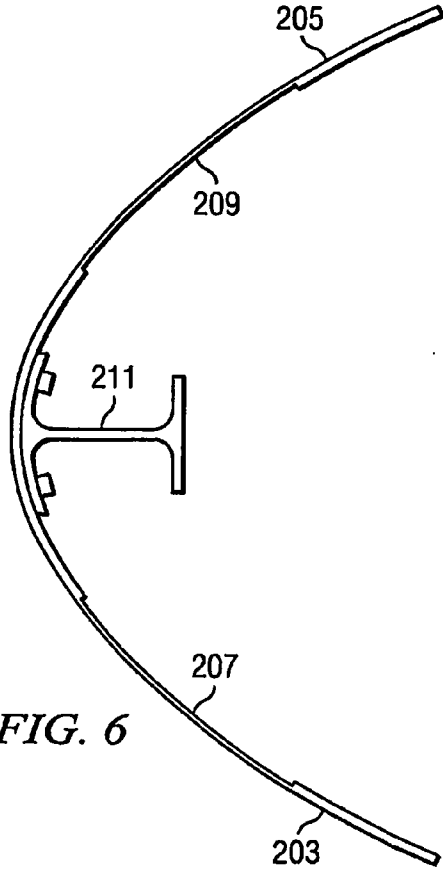


FIG. 6

## PROTECTIVE SKIN FOR AIRCRAFT

### TECHNICAL FIELD

[0001] The present invention relates to skins for aircraft. In particular, the present invention relates to skins for protecting aircraft from impact damage.

### DESCRIPTION OF THE PRIOR ART

[0002] Modern aircraft are manufactured from a wide variety materials, including steel, aluminum, and a wide variety of composite materials. Most of the structural components are made from strong, rigid materials. However, in order to conserve weight, the skin of the aircraft is often made from a thin sheet of metal or composite. Because these skins are so thin, leading edges of wings and stabilizers are usually reinforced with protective layers or strips of material.

[0003] Even with protective layers and strips of reinforcing material, the leading edges of wings and stabilizers are susceptible to impact damage from flying objects and birds. For example, when a bird impacts the leading edge of an aircraft wing or vertical stabilizer, it can pass completely through the skin and protective layers to the interior substructure of ribs, spars, and control components. Such damage to the leading edge and substructure can lead to catastrophic failure of the aircraft. If the aircraft can be safely landed, the only way to repair the damage is to completely replace the wing or stabilizer. Complete replacement of wings and stabilizers is very time consuming and costly.

[0004] The only way to protect against critical damage to the substructure is to add additional components and extra substructure. This is very costly and adds extra weight to the aircraft. In many cases, space constraints prevent the addition of adequate protection from such impact damage.

### SUMMARY OF THE INVENTION

[0005] There is a need for a protective skin for an aircraft that can absorb the impact of and minimize the damage from collisions with flying objects and birds.

[0006] Therefore, it is an object of the present invention to provide a protective skin for an aircraft that can absorb the impact of and minimize the damage from collisions with flying objects and birds.

[0007] This object is achieved by providing a protective skin for the leading edges of wing members, horizontal stabilizers, and vertical fins in which a portion of the skin material is removed in a selected pattern from the interior surface of the skin. In the preferred embodiment, the interior surface of the skin is chemically etched in oval and rectangular patterns so as to create crumple zones and generate progressive failure of the metal. This allows the leading edge to absorb the impact energy from a collision with a bird or other object, and prevent the bird or other object from penetrating through the leading edge into the substructure. In applications in which the radius of curvature of the leading edge is relatively large, or where there is adequate space, an I-beam shaped stiffener may be added behind the skin to provide additional stiffness.

[0008] The present invention provides significant advantages, including: (1) impacts from birds and other objects

can be absorbed without affecting the substructure of the aircraft; (2) penetration of the leading edge by a bird or other object can be eliminated or significantly reduced; (3) the leading edge can be normally stiffened without any weight increase; and (4) the failure response of the leading edge can be locally tuned by selectively shaping, sizing, and orienting the pockets on the interior surface of the skin.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0010] FIG. 1 is a perspective view of an aircraft having a protective skin according to the present invention.

[0011] FIG. 2 is a schematic of the skin forming the leading edges of the horizontal stabilizers of the aircraft of FIG. 1.

[0012] FIG. 3 is a cross-sectional view of the skin of FIG. 2 taken at III-III in FIG. 2.

[0013] FIG. 4 is a cross-sectional view of the skin of FIG. 2 taken at IV-IV in FIG. 2.

[0014] FIG. 5 is a schematic of the skin forming the leading edge of the vertical tail fin of the aircraft of FIG. 1.

[0015] FIG. 6 is a cross-sectional view of the skin of FIG. 5 taken at VI-VI in FIG. 5.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] The present invention involves a method and apparatus for protecting the substructure of an aircraft from damage due to leading edges impact with flying objects, such as birds. Although the present invention will be described with reference to a tiltrotor aircraft, it will be appreciated that the present invention may be used on any type of aircraft in which it is desirable to provide such protection.

[0017] Referring to FIG. 1 in the drawings, a tiltrotor aircraft 111 having a protective skin according to the present invention is illustrated. Tiltrotor aircraft are unique rotorcraft in that they have tiltrotor assemblies that operate between a helicopter mode in which the tiltrotor assemblies are rotated upward allowing the tiltrotor aircraft to take off, hover, fly, and land like a conventional helicopter; and an airplane mode, in which the tiltrotor assemblies are tilted forward allowing the tiltrotor aircraft to fly like a conventional fixed-wing propeller driven aircraft. The first tiltrotor aircraft were designed strictly for military purposes, but now efforts are being made to manufacture civilian-type tiltrotor aircraft, and "Quad" tiltrotor aircraft having two sets of wing assemblies and four tiltrotor nacelle assemblies. In FIG. 1, tiltrotor aircraft 111 is a civilian-type tiltrotor aircraft shown in the airplane mode.

[0018] Tiltrotor aircraft 111 includes a fuselage 120, one or more wing members 117a and 117b coupled to fuselage 120, at least one vertical tail fin 113 connected to fuselage 120, and one or more horizontal stabilizers 116a and 116b

connected to vertical tail fin **113**. A pair of nacelle assemblies **115a** and **115b** are carried by wing members **117a** and **117b** and are typically disposed at end portions **119a** and **119b** of wing members **117a** and **117b**, respectively. Tiltrotor nacelle assemblies **115a** and **115b** include nacelles **121a** and **121b** that house the engines, transmissions, and prop rotor gearboxes that drive prop rotors **123a** and **123b**. Prop rotors **123a** and **123b** are disposed on the forward ends **125a** and **125b** of nacelles **121a** and **121b**, and include hubs **124a** and **124b** and prop rotor blades **127a** and **127b**, respectively. As is conventional with tiltrotor aircraft, prop rotors **123a** and **123b** counter-rotate relative to each other, i.e., prop rotor **123a** rotates counterclockwise and prop rotor **123b** rotates clockwise if viewed looking in the aft direction while tiltrotor aircraft **111** is in the airplane mode.

[0019] Tiltrotor nacelle assemblies **115a** and **115b** rotate relative to wing members **117a** and **117b** between the helicopter mode in which tiltrotor nacelle assemblies **115a** and **115b** are tilted upward, such that tiltrotor aircraft **111** can take off, hover, fly, and land like a conventional helicopter; and the airplane mode in which tiltrotor nacelle assemblies **115a** and **115b** are tilted forward, such that tiltrotor aircraft **111** flies like a conventional fixed-wing propeller driven aircraft.

[0020] Wing members **117a** and **117b** have leading edges **131a** and **131b**; horizontal stabilizers **116a** and **116b** have leading edges **133a** and **133b**; and vertical tail fin **113** has a leading edge **135**. According to the present invention, leading edges **131a** and **131b** are formed from impact skins **141a** and **141b**, respectively; leading edges **133a** and **133b** are formed from impact skins **143a** and **143b**, respectively; and leading edge **135** is formed from an impact skin **145**. Impact skins **141a**, **141b**, **143a**, **143b**, and **145** are preferably manufactured from a metallic material and are configured to provide protection against bird strikes and impacts by other objects during the operation of tiltrotor aircraft **111**.

[0021] Referring now to FIG. 2 in the drawings, impact skins **143a** and **143b** are shown in a schematic perspective view. It will be appreciated that the following discussion with respect to impact skins **143a** and **143b** applies to impact skins **141a**, **141b**, and **145** as well.

[0022] Impact skin **143a** forms a curved airfoil surface that is symmetrical about a waterline axis **147a**, such that impact surface **143a** has an upper airfoil surface **151a** and a lower airfoil surface **153a**. Likewise, impact surface **143b** forms a curved airfoil surface that is symmetrical about a waterline axis **147b**, such that impact surface **143b** has an upper airfoil surface **151b** and a lower airfoil surface **153b**.

[0023] In accordance with the present invention, a plurality of recessed pockets **155a** and **157a** are formed in the interior portion of upper airfoil surface **151a**, and a plurality of recessed pockets **159a** and **161a** are formed in the interior portion of lower airfoil surface **153a**. In a similar fashion, a plurality of recessed pockets **155b** and **157b** are formed in the interior portion of upper airfoil surface **151b**, and a plurality of recessed pockets **159b** and **161b** are formed in the interior portion of lower airfoil surface **153b**. Recessed pockets **155a**, **157a**, **159a**, **161a**, **155b**, **157b**, **159b**, and **161b** are selectively sized, shaped, recessed, arranged, and contoured to create crumple zones and generate progressive failure of impact surfaces **143a** and **143b**. In the preferred embodiment, recessed pockets **155a**, **157a**, **159a**, **161a**,

**155b**, **157b**, **159b**, and **161b** create alternating strong and soft regions in impact surfaces **143a** and **143b**. This allows impact surfaces **143a** and **143b** to absorb the impact energy from a collision with a bird or other object, and prevent the bird or other object from penetrating through impact surfaces **143a** and **143b** into the substructure of tiltrotor aircraft **111**.

[0024] It should be understood that the size, shape, depth, arrangement, and contour of recessed pockets **155a**, **157a**, **159a**, **161a**, **155b**, **157b**, **159b**, and **161b**, may be selectively altered to produce different impact and crumple characteristics. In the preferred embodiment, recessed pockets **155a** and **159a**, which are generally located in inboard positions, have oval and circular shapes; and recessed pockets **157a** and **159a**, which are generally located in outboard positions, have rectangular shapes. It will be appreciated that in some applications it may be desirable to form fewer pockets or join the pockets together to form longer shapes and patterns. For example, one or more elongated pockets extending in the directions of waterline axes **147a** and **147b** in sinusoidal shapes may be used.

[0025] In the preferred embodiment, impact skins **143a** and **143b** are made of a metallic material, such as aluminum, and recessed pockets **155a**, **157a**, **159a**, **161a**, **155b**, **157b**, **159b**, and **161b** are chemically etched and/or mechanically milled into the interior portions of upper and lower airfoil surfaces **151a**, **151b**, **153a**, and **153b**. Due to the sharp curvature along station axes **147a** and **147b**, impact skins **143a** and **143b** are sufficiently stiff for normal operation and do not require additional stiffeners.

[0026] Impact skins **143a** and **143b** preferably include one or more local ribs **171** to facilitate attachment to the substructure of horizontal stabilizers **116a** and **116b**. Local ribs **171** are preferably attached to the substructure of horizontal stabilizers **116a** and **116b** by rivets or other suitable means, and support and maintain the shape of impact skins **143a** and **143b**.

[0027] Referring now to FIGS. 3 and 4 in the drawings, impact skins **143a** and **143b** are shown in cross-sectional views taken at III-III and IV-IV, respectively. Waterline axes **175** and forward outboard spar planes **177** of horizontal stabilizers **116a** and **116b** have been included to illustrate the preferred relative location and orientation of impact skins **143a** and **143b**. As is shown, in the preferred embodiment, about one half of the thickness of the upper and lower airfoil surfaces are removed by chemical etching and/or mechanically milled to form recessed pockets **155a**, **159a**, **157b**, and **161b**.

[0028] The size, shape, contour, and relative location of each pocket is selectively chosen depending upon the where the pocket is located along station axes **147a** and **147b**. For example, at inboard locations along horizontal stabilizers **116a** and **116b** where the radius of curvature of impact skin **143a** is greater (see FIG. 4), pockets **155a** and **159a** may be located farther aft on upper and lower airfoil surfaces **151a** and **153a**; and at outboard locations where the radius of curvature of impact skin **143b** is greater (see FIG. 3), pockets **157b** and **161b** may be located farther forward on upper and lower airfoil surfaces **151a** and **153a**.

[0029] Referring now to FIGS. 5 and 6 in the drawings, impact skin **145** forming the leading edge of vertical tail fin

**113** is illustrated. Impact skin **145** is symmetrical about a buttlane axis **201**, such that impact surface **145** has a right airfoil surface **203** and a left airfoil surface **205**. In accordance with the present invention, a plurality of recessed pockets **207** are formed in the interior portion of right airfoil surface **203**, and a plurality of recessed pockets **209** are formed in the interior portion of left airfoil surface **205**. As with impact skins **143a** and **143b**, it is preferred that impact skin **145** be made of a metallic material, such as aluminum, and recessed pockets **207** and **209** be chemically etched and/or mechanically milled into the interior portions of right and left airfoil surfaces **203** and **205**. In this manner, recessed pockets **207** and **209** perform the same functions as recessed pockets **155a**, **157a**, **159a**, **161a**, **155b**, **157b**, **159b**, and **161b**.

[0030] Impact skin **145** is similar in form and function to impact skins **143a** and **143b** and is preferably attached to the substructure of vertical tail fin **113** by rivets or other suitable means. However, due to the relatively large radius of curvature along buttlane axis **201**, and due to the availability of space within vertical tail fin **113**, it is preferred that impact skin **145** include an additional stiffening means, such as an I-beam shaped stiffener **211** extending along a buttlane axis **203** of vertical tail fin **113**. Stiffener **211** is connected to the interior portion of impact skin **145** to provide additional stiffness and support to impact skin **145**. It is not necessary that stiffener **211** be directly connected to the substructure of vertical tail fin **113**.

[0031] Recessed pockets **207** and **209** are selectively sized, shaped, recessed, arranged, and contoured to create crumple zones and generate progressive failure of impact skin **145**. Recessed pockets **207** and **209** create alternating strong and soft regions in impact skin **145**. This allows impact skin **145** to absorb the impact energy from a collision with a bird or other object, and prevent the bird or other object from penetrating through impact skin **145** into the substructure of tiltrotor aircraft **111**.

[0032] It should be understood that the size, shape, depth, arrangement, and contour of recessed pockets **207** and **209** may be selectively altered to produce different impact and crumple characteristics. For example, recessed pockets **207** and **209**, which are generally located in higher positions, have circular shapes; and recessed pockets **207** and **209**, which are generally located in lower positions, have oval shapes. It will be appreciated that in some applications it may be desirable to form fewer pockets or join the pockets together to form longer shapes and patterns. For example, one or more elongated pockets extending in the directions of buttlane axis **201** in sinusoidal shapes may be used.

[0033] In operation, if a bird or other flying object collides with impact skin **145**, pockets **207** and **209** deform outward and inward due to the reduced thickness of pockets **207** and **209**, thereby absorbing the impact energy of the bird and preventing the bird from penetrating through impact skin **145** into the substructure of aircraft **111**. This expansion-type deformation creates crumple zones and generates progressive failure of impact skin **145**, thereby saving the substructure of aircraft **111**.

[0034] It is apparent that an invention with significant advantages has been described and illustrated. Although the present invention is shown in a limited number of forms, it

is not limited to just these forms, but is amenable to various changes and modifications without departing from the spirit thereof.

1. A protective skin for an aircraft comprising:

a leading edge member forming an airfoil surface having an exterior surface and an opposing interior surface;

at least one pocket recessed into the interior surface, each pocket having a thickness that is less than the thickness of the leading edge member, each pocket being configured to deform in response to an impact from an object with the leading edge member.

2. The protective skin according to claim 1, wherein the leading edge member forms the leading edge of a wing member.

3. The protective skin according to claim 1, wherein the leading edge member forms the leading edge of a horizontal stabilizer.

4. The protective skin according to claim 1, wherein the leading edge member forms the leading edge of a vertical fin.

5. The protective skin according to claim 1, wherein the pockets are formed by a chemical etching process.

6. The protective skin according to claim 1, wherein the pockets are formed by a mechanical milling process.

7. The protective skin according to claim 1, wherein the leading edge member is curved about a longitudinal axis so as to form an upper airfoil surface and a lower airfoil surface.

8. The protective skin according to claim 7, wherein the at least one pocket comprises:

a plurality of pockets arranged in a selected pattern over the interior surfaces of the upper airfoil surface and the lower airfoil surface.

9. The protective skin according to claim 8, wherein each pocket is formed in one of the following geometric shapes: circle, oval, rectangle, square.

10. The protective skin according to claim 8, wherein the pattern of pockets on the interior surface of the upper airfoil surface is a mirror image of the pattern of pockets on the interior surface of the lower airfoil surface.

11. The protective skin according to claim 8, wherein the pattern of pockets on the interior surface of the upper airfoil surface is not a mirror image of the pattern of pockets on the interior surface of the lower airfoil surface.

12. The protective skin according to claim 1, further comprising:

at least one rib member connected to the interior surface of the leading edge member for attaching the leading edge member to a substructure of the aircraft.

13. The protective skin according to claim 1, further comprising:

a stiffening means connected to the interior surface of the leading edge member for providing localized stiffness to the leading edge member.

**14.** The protective skin according to claim 13, wherein the stiffening means is an elongated I-shaped beam.

**15.** The protective skin according to claim 13, wherein the stiffening means is not connected to a substructure of the aircraft.

**16.** The protective skin according to claim 13, wherein the stiffening means is also connected to a substructure of the aircraft.

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